AMENDMENTS TO THE CLAIMS

1. (Original) A tracking error detection apparatus comprising:

a photodetector comprising four photoreceptor elements which are partitioned along a tangential direction and a perpendicular direction with respect to an information track that is recorded as an information pit line on a recording medium;

zerocross detection circuits for detecting zerocross points at which two sequences of digital signals intersect center levels of the respective digital signals, each of said two sequences of digital signals being obtained by adding output signals from the two photoreceptor elements positioned on a diagonal line, among four signals that are generated according to the amounts of received by the respective photoreceptor elements and are outputted from the photodetector;

a phase difference detection circuit for performing phase comparison using a distance between the zerocross points of the two sequences of digital signals, and outputting a result of phase comparison obtained between the respective zerocross points, as a pulse signal corresponding to one sampling clock; and

a low-pass filter for performing band restriction to a signal outputted from the phase difference detection circuit, thereby to obtain a tracking error signal.

2. (Original) A tracking error detection apparatus as defined in Claim 1 wherein said phase difference detection circuit comprises:

a phase difference calculation unit for calculating a distance between the zerocross points of the two sequences of digital signals, and successively outputting the distance as a result of phase comparison;

a pulse generation unit for generating pulse signals each corresponding to one sampling clock at positions where the two sequences of digital signals perform zerocross, and outputting, as a phase comparison end pulse, a pulse signal that appears later at a point where phase comparison is carried out, between the generated pulse signals corresponding to the two sequences of digital signals; and

a data switching unit for outputting each of the results of phase comparison between the respective zerocross points, which have been successively outputted from the phase difference

calculation unit, as a pulse signal corresponding to one sampling clock, at the timing of the phase comparison end pulse outputted from the pulse generation unit.

3. (Original) A tracking error detection apparatus comprising:

a photodetector comprising four photoreceptor elements which are partitioned along a tangential direction and a perpendicular direction with respect to an information track that is recorded as an information pit line on a recording medium;

zerocross detection circuits for detecting zerocross points at which two sequences of digital signals intersect center levels of the respective digital signals, each of said two sequences of digital signals being obtained by adding output signals from the two photoreceptor elements positioned on a diagonal line, among four signals that are generated according to the amounts of light received by the respective photoreceptor elements and are outputted from the photodetector;

a pulse width detection circuit for detecting a pulse width of sampling data of the two sequences of digital signals;

a phase difference detection circuit for performing phase comparison using the distance between the zerocross points of the two sequences of digital signals, and outputting a result of phase comparison; and

a low-pass filter for performing band restriction to a signal outputted from the phase difference detection circuit, thereby to obtain a tracking error signal;

wherein, when the pulse width detected by the pulse width detection circuit is equal to or shorter than a predetermined value, said phase difference detection circuit does not perform phase comparison at this pulse.

4. (Original) A tracking error detection apparatus as defined in Claim 3 wherein said phase difference detection circuit comprises:

a phase difference calculation unit for calculating a distance between the zerocross points of the two sequences of digital signals, and successively outputting the distance as a result of phase comparison;

a pulse generation unit for generating pulse signals each corresponding to one sampling clock at positions where the two sequences of digital signals perform zerocross, and outputting, as a phase comparison end pulse, a pulse signal that appears later at a point where phase comparison is carried out, between the generated pulse signals corresponding to the two sequences of digital signals;

an invalid pulse cancel unit for, when the pulse width detected by the pulse width detection circuit is equal to or shorter than a predetermined value, treating the corresponding pulse as an invalid pulse, and canceling phase comparison at this invalid pulse in the phase difference calculation unit; and

a data updation unit for updating the output data using the result of phase comparison that is successively outputted from the phase difference calculation unit, at every phase comparison end pulse outputted from the pulse generation unit, and maintaining the output level of the output data until the next phase comparison end pulse arrives.

5. (Original) A tracking error detection apparatus as defined in Claim 3 wherein said phase difference detection circuit comprises:

a phase difference calculation unit for calculating a distance between the zerocross points of the two sequences of digital signals, and successively outputting the distance as a result of phase comparison;

a pulse generation unit for generating pulse signals each corresponding to one sampling clock at positions where the two sequences of digital signals perform zerocross, and outputting, as a phase comparison end pulse, a pulse signal that appears later at a point where phase comparison is carried out, between the generated pulse signals corresponding to the two sequences of digital signals;

an invalid pulse cancel unit for, when the pulse width detected by the pulse width detection circuit is equal to or shorter than a predetermined value, treating the corresponding pulse as an invalid pulse, and canceling phase comparison at this invalid pulse in the phase difference calculation unit; and

a data updation unit for

updating the output data using the result of phase comparison that is successively outputted from the phase difference calculation unit for every phase comparison end pulse outputted from the pulse generation unit, and maintaining the output level of the output data until the next phase comparison end pulse arrives, and

updating the output data using the average of the plural results of phase difference comparison that are obtained in the phase difference calculation unit before and/or after the invalid pulse, at the timing of the invalid pulse, when receiving a signal from the invalid pulse cancel unit indicating that the invalid pulse is canceled in the phase difference calculation unit.

6. (Original) A tracking error detection apparatus as defined in Claim 3 wherein said phase difference detection circuit comprises:

a phase difference calculation unit for calculating a distance between the zerocross points of the two sequences of digital signals, and successively outputting the distance as a result of phase comparison;

a pulse generation unit for generating pulse signals each corresponding to one sampling clock at positions where the two sequences of digital signals perform zerocross, and outputting, as a phase comparison end pulse, a pulse signal that appears later at a point where phase comparison is carried out, between the generated pulse signals corresponding to the two sequences of digital signals;

an invalid pulse cancel unit for, when the pulse width detected by the pulse width detection circuit is equal to or shorter than a predetermined value, treating the corresponding pulse as an invalid pulse, and canceling phase comparison at this invalid pulse in the phase difference calculation unit; and

a data switching unit for

outputting each of the results of phase comparison between the respective zerocross points, which have been successively outputted from the phase difference calculation unit, as a pulse signal corresponding to one sampling clock, at the timing of the phase comparison end pulse outputted from the pulse generation unit, and

outputting the previous result of phase difference comparison obtained in the phase difference calculation unit, as a pulse signal corresponding to one sampling clock, at the timing of the invalid pulse, when receiving a signal indicating that the invalid pulse is canceled in the phase difference calculation unit.

7. (Original) A tracking error detection apparatus as defined in Claim 3 wherein said phase difference detection circuit comprises:

a phase difference calculation unit for calculating a distance between the zerocross points of the two sequences of digital signals, and successively outputting the distance as a result of phase comparison;

a pulse generation unit for generating pulse signals each corresponding to one sampling clock at positions where the two sequences of digital signals perform zerocross, and outputting, as a phase comparison end pulse, a pulse signal that appears later at a point where phase comparison is carried out, between the generated pulse signals corresponding to the two sequences of digital signals;

an invalid pulse cancel unit for, when the pulse width detected by the pulse width detection circuit is equal to or shorter than a predetermined value, treating the corresponding pulse as an invalid pulse, and canceling phase comparison at invalid pulse in the phase difference calculation unit; and

a data switching unit for

outputting each of the results of phase comparison between the zerocross points, which have been successively outputted from the phase difference calculation unit, as a pulse signal corresponding to one sampling clock, at the timing of the phase comparison end pulse outputted from the pulse generation unit, and

outputting the average of the plural results of phase difference comparison obtained before and/or after the invalid pulse in the phase difference calculation unit, as a pulse signal corresponding to one sampling clock, at the timing of the invalid pulse, when receiving a signal from the invalid pulse cancel unit indicating that the invalid pulse is canceled in the phase difference calculation unit.

8. (Currently Amended) A tracking error detection apparatus as defined in ~~any of Claims~~ Claim 4 ~~to 7~~ wherein, when an H-side pulse width and/or an L-side pulse width, which are detected by the pulse width detection circuit, are/is equal to or shorter than a predetermined value, said invalid pulse cancel unit treats the corresponding pulse as an invalid pulse, and cancels phase comparison with this invalid pulse in the phase difference calculation unit.

9. (Currently Amended) A tracking error detection apparatus as defined in ~~any of Claims~~ Claim 4 ~~to 7~~ further comprising an amplitude detection circuit for detecting envelope signals of the two sequences of digital signals, and operating the invalid pulse cancel unit only when the values of the envelope signals are equal to or lower than a predetermined threshold value.

10. (Currently Amended) A tracking error detection apparatus as defined in ~~any of Claims~~ Claim 1 ~~to 7~~ further comprising high-pass filters for removing frequencies equal to and lower than predetermined cutoff frequencies of the two sequences of digital signals.

11. (Original) A tracking error detection apparatus comprising:

a photodetector comprising four photoreceptor elements which are partitioned along a tangential direction and a perpendicular direction with respect to an information track that is recorded as an information pit line on a recording medium;

high-pass filters for removing frequencies equal to and lower than predetermined cutoff frequencies of two sequences of digital signals, respectively, said two sequences of digital signals being obtained by adding the output signals from two photoreceptor elements positioned on a diagonal line, among four signals that are generated according to the amounts of light received by the respective photoreceptor elements and are outputted from the photodetector;

zerocross detection circuits for detecting zerocross points at which the two sequences of digital signals intersect center levels of the respective digital signals, from the two sequences of digital signals in which the frequencies equal to and lower than the predetermined cutoff frequencies are removed;

a phase difference detection circuit for performing phase comparison using a distance between the zerocross points of the two sequences of digital signals, and outputting a result of phase comparison; and

a low-pass filter for performing band restriction to a signal outputted from the phase difference detection circuit, thereby to obtain a tracking error signal.

12. (Original) A tracking error detection apparatus comprising:

a photodetector comprising four photoreceptor elements which are partitioned along a tangential direction and a perpendicular direction with respect to an information track that is recorded as an information pit line on a recording medium;

zerocross detection circuits for detecting zerocross points at which four sequences of digital signals intersect center levels of the respective digital signals, said four sequences of digital signals being generated according to the amounts of light received by the respective photoreceptor elements and are outputted from the photodetector;

a first phase difference detection circuit for performing phase comparison using a distance between the zerocross points of two sequences of digital signals that are obtained from the photoreceptor elements positioned forward in the advancing direction of the information track, among the zerocross points of the four sequences of digital signals, and outputting a result of phase comparison between the zerocross point, as a pulse signal corresponding to one sampling clock;

a second phase difference detection circuit for performing phase comparison using a distance between the zerocross points of photoreceptor elements positioned backward in the advancing direction of the information track, among the zerocross points of the four sequences of digital signals, and outputting the result of phase comparison between the zerocross points, as a pulse signal corresponding to one sampling clock;

an addition circuit for adding the output signals of the first and second phase different detection circuits; and

a low-pass filter for performing band restriction to a signal outputted from the addition circuit, thereby to obtain a tracking error signal.

13. (Original) A tracking error detection apparatus as defined in Claim 12 wherein each of said first and second phase difference detection circuits comprises:

a phase difference calculation unit for calculating a distance between the zerocross points of the two sequences of digital signals, and successively outputting the distance as a result of phase comparison;

a pulse generation unit for generating pulse signals each corresponding to one sampling clock at positions where the two sequences of digital signals perform zerocross, and outputting, as a phase comparison end pulse, a pulse signal that appears later at a point where phase comparison is carried out, between the generated pulse signals corresponding to the two sequences of digital signals; and

a data switching unit for outputting each of the results of phase comparison between the zerocross points, which have been successively outputted from the phase difference calculation unit, as a pulse signal corresponding to one sampling clock, at the timing of the phase comparison end pulse outputted from the pulse generation unit.

14. (Original) A tracking error detection apparatus comprising:

a photodetector comprising four photoreceptor elements which are partitioned along a tangential direction and a perpendicular direction with respect to an information track that is recorded as an information pit line on a recording medium;

zerocross detection circuits for detecting zerocross points at which four sequences of digital signals intersect center levels of the respective digital signals, said four sequences of digital signals being generated according to the amounts of light received by the respective photoreceptor elements and are outputted from the photodetector;

a first pulse width detection circuit for detecting pulse widths of sampling data of two sequences of digital signals that are obtained from the photoreceptor elements placed forward in the advancing direction of the information track, among the four sequences of digital signals;

a second pulse width detection circuit for detecting pulse widths of sampling data of two sequences of digital signals that are obtained from the photoreceptor elements placed backward in the advancing direction of the information track, among the four sequences of digital signals;

a first phase difference detection circuit for performing phase comparison using a distance between the zerocross points of the two sequences of digital signals that are obtained from the photoreceptor elements positioned forward in the advancing direction of the information track, among the zerocross points of the four sequences of digital signals, and outputting the result of phase comparison between the zerocross points, as a pulse signal corresponding to one sampling clock;

a second phase difference detection circuit for performing phase comparison using a distance between the zerocross points of the two sequences of digital signals that are obtained from the photoreceptor elements positioned backward in the advancing direction of the information track, among the zerocross points of the four sequences of digital signals, and outputting the result of phase comparison between the zerocross points, as a pulse signal corresponding to one sampling clock;

an addition circuit for adding the output signals of the first and second phase different detection circuits; and

a low-pass filter for performing band restriction to a signal outputted from the addition circuit, thereby to obtain a tracking error signal;

wherein, when the pulse width detected by the first pulse width detection circuit is equal to or lower than a predetermined value, the first phase difference detection circuit does not perform phase comparison at the detected pulse, and

when the pulse width detected by the second pulse width detection circuit is equal to or lower than a predetermined value, the second phase difference detection circuit does not perform phase comparison at the detected pulse.

15. (Original) A tracking error detection apparatus as defined in claim 14 wherein each of said first and second phase difference detection circuits comprises:

a phase difference calculation unit for calculating a distance between the zerocross points of the two sequences of digital signals, and successively outputting the distance as a result of phase comparison;

a pulse generation unit for generating pulse signals each corresponding to one sampling clock at positions where the two sequences of digital signals perform zerocross, and outputting, as a phase

comparison end pulse, a pulse signal that appears later at a point where phase comparison is carried out, between the generated pulse signals corresponding to the two sequences of digital signals;

an invalid pulse cancel unit for, when the pulse width detected by the first or second pulse width detection circuit is equal to or shorter than a predetermined value, treating the corresponding pulse as an invalid pulse, and canceling phase comparison at this invalid pulse in the phase difference calculation unit; and

a data updation unit for updating the output data using the result of phase comparison that is successively outputted from the phase difference calculation unit, at every phase comparison end pulse outputted from the pulse generation unit, and maintaining the output level of the output data until the next phase comparison end pulse arrives.

16. (Original) A tracking error detection apparatus as defined in Claim 14 wherein each of said first and second phase difference detection circuits comprises:

a phase difference calculation unit for calculating a distance between the zerocross points of the two sequences of digital signals, and successively outputting the distance as a result of phase comparison;

a pulse generation unit for generating pulse signals each corresponding to one sampling clock at positions where the two sequences of digital signals perform zerocross, and outputting, as a phase comparison end pulse, a pulse signal that appears later at a point where phase comparison is carried out, between the generated pulse signals corresponding to the two sequences of digital signals;

an invalid pulse cancel unit for, when the pulse width detected by the first or second pulse width detection circuit is equal to or shorter than a predetermined value, treating the corresponding pulse as an invalid pulse, and canceling phase comparison at this invalid pulse in the phase difference calculation unit; and

a data updation unit for

updating the output data using the result of phase comparison that is successively outputted from the phase difference calculation unit for every phase comparison end pulse outputted

from the pulse generation unit, and maintaining the output level of the output data until the next phase comparison end pulse arrives, and

updating the output data using the average of the plural results of phase difference comparison that are obtained in the phase difference calculation unit before and/or after the invalid pulse, at the timing of the invalid pulse, when receiving a signal from the invalid pulse cancel unit indicating that the invalid pulse is canceled in the phase difference calculation unit.

17. (Original) A tracking error detection apparatus as defined in Claim 14 wherein each of said first and second phase difference detection circuits comprises:

a phase difference calculation unit for calculating the distance between the zerocross points of the two sequences of digital signals, and successively outputting the distance as a result of phase comparison;

a pulse generation unit for generating pulse signals each corresponding to one sampling clock at positions where the two sequences of digital signals perform zerocross, and outputting, as a phase comparison end pulse, a pulse signal that appears later at a point where phase comparison is carried out, between the generated pulse signals corresponding to the two sequences of digital signals;

an invalid pulse cancel unit for, when the pulse width detected by the first or second pulse width detection circuit is equal to or shorter than a predetermined value, treating the corresponding pulse as an invalid pulse, and canceling phase comparison at this invalid pulse in the phase difference calculation unit; and

a data switching unit for

outputting the result of phase comparison that is successively outputted from the phase difference calculation unit, as a pulse signal corresponding to one sampling clock, at the timing of the phase comparison end pulse outputted from the pulse generation unit, and

outputting the previous result of phase difference comparison obtained in the phase difference calculation unit, as a pulse signal corresponding to one sampling clock, at the timing of the invalid pulse, when receiving a signal indicating that the invalid pulse is canceled in the phase difference calculation unit.

18. (Original) A tracking error detection apparatus as defined in Claim 14 wherein each of said first and second phase difference detection circuit comprises:

a phase difference calculation unit for calculating a distance between the zerocross points of the two sequences of digital signals, and successively outputting the distance as a result of phase comparison;

a pulse generation unit for generating pulse signals each corresponding to one sampling clock at positions where the two sequences of digital signals perform zerocross, and outputting, as a phase comparison end pulse, a pulse signal that appears later at a point where phase comparison is carried out, between the generated pulse signals corresponding to the two sequences of digital signals;

an invalid pulse cancel unit for, when the pulse width detected by the first or second pulse width detection circuit is equal to or shorter than a predetermined value, treating the corresponding pulse as an invalid pulse, and canceling phase comparison at this invalid pulse in the phase difference calculation unit; and

a data switching unit for

outputting the result of phase comparison between the respective zerocross points, which have been successively outputted from the phase difference calculation unit, as a pulse signal corresponding to one sampling clock, at the timing of the phase comparison end pulse outputted from the pulse generation unit, and

outputting the average of the plural results of phase difference comparison which are obtained before and/or after the invalid pulse in the phase difference calculation unit, as a pulse signal corresponding to one sampling clock, at the timing of the invalid pulse, when receiving a signal from the invalid pulse cancel unit indicating that the invalid pulse is canceled in the phase difference calculation unit.

19. (Currently Amended) A tracking error detection apparatus as defined in ~~any of Claims~~ Claim 15 ~~to 18~~ wherein,

when an H-side pulse width and/or an L-side pulse width, which are detected by the first or second pulse width detection circuit, are/is equal to or shorter than a predetermined value, said

invalid pulse cancel unit treats the corresponding pulse as an invalid pulse, and cancels phase comparison with this invalid pulse in the phase difference calculation unit.

20. (Currently Amended) A tracking error detection apparatus as defined in ~~any of Claims~~ Claim 15 ~~to 18~~ further comprises:

a first amplitude detection circuit for detecting envelope signals of the two sequences of digital signals which are obtained from the photoreceptor elements positioned forward in the advancing direction of the information track, among the four sequences of digital signals, and operating the invalid pulse cancel unit only when the values of the envelope signals are equal to or lower than a predetermined threshold value; and

a second amplitude detection circuit for detecting envelope signals of the two sequences of digital signals which are obtained from the photoreceptor elements positioned backward in the advancing direction of the information track, among the four sequences of digital signals, and operating the invalid pulse cancel unit only when the values of the envelope signals are equal to or lower than a predetermined threshold value.

21. (Currently Amended) A tracking error detection apparatus as defined in ~~any of Claims~~ Claim 12 ~~to 18~~ further comprising high-pass filters for removing frequencies equal to and lower than predetermined cutoff frequencies of the four sequences of digital signals.

22. (Original) A tracking error detection apparatus comprising:

a photodetector comprising four photoreceptor elements which are partitioned along a tangential direction and a perpendicular direction with respect to an information track that is recorded as an information pit line on a recording medium;

high-pass filters for removing frequencies equal to and lower than predetermined cutoff frequencies of four sequences of digital signals obtained according to the amounts of light received by the respective photoreceptor elements and are outputted from the photodetector;

zerocross detection circuits for detecting zerocross points at which the four sequences of digital signals intersect center levels of the respective digital signals, from the four sequences of digital signals in which the frequencies equal to and lower than the predetermined cutoff frequencies are removed;

a first phase difference detection circuit for performing phase comparison using the distance between the zerocross points of the two sequences of digital signals obtained from the photoreceptor elements positioned forward in the advancing direction of the information track, among the zerocross points of the four sequences of digital signals, and outputting a result of phase comparison;

a second phase difference detection circuit for performing phase comparison using the distance between the zerocross points of the two sequences of digital signals obtained from the photoreceptor elements positioned backward in the advancing direction of the information track, among the zerocross points of the four sequences of digital signals, and outputting a result of phase comparison;

an addition circuit for adding the output signals from the first and second phase difference detection circuits; and

a low-pass filter for performing band restriction to a signal outputted from the phase difference detection circuit, thereby to obtain a tracking error signal.

23. (New) A tracking error detection apparatus as defined in Claim 3 further comprising high-pass filters for removing frequencies equal to and lower than predetermined cutoff frequencies of the two sequences of digital signals.

24. (New) A tracking error detection apparatus as defined in Claim 14 further comprising high-pass filters for removing frequencies equal to and lower than predetermined cutoff frequencies of the four sequences of digital signals.